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DEEPLY VIRTUAL COMPTON SCATTERING AND PROMPT PHOTON PRODUCTION AT HERA

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Recent results on the Deeply Virtual Compton Scattering (DVCS) and prompt photon productions from H1 and ZEUS experiments on the ep collider HERA are presented. A new DVCS cross section measurements of the H1 Collaboration, for photon virtualities $Q^2 > 4$ GeV^2 and photon-proton c.m.s. energy $30 < W < 140$ GeV, are discussed and compared to NLO QCD calculations encoding Generalized Parton Distributions (GPDs) and to Colour Dipole model predictions. For the first time the cross section dependence is reported on the momentum transfer squared at the proton vertex, t. Prompt photon production in deep inelastic scattering and photoproduction are presented both in the inclusive case and in the presence of a jet. The results are compared to NLO QCD predictions.

1 Introduction

This paper presents new and recent results on two processes allowing for test of QCD in the perturbative regime (pQCD) and containing a measured photon in the final state.
1) Deeply Virtual Compton Scattering (DVCS), $ep \to e\gamma p$, sketched in Fig. 1a, consists of the hard diffractive scattering of a virtual photon off a proton. The interest of the DVCS process resides in the particular insight it gives to the applicability of perturbative Quantum Chromo Dynamics (QCD) in the field of diffractive interactions and to the nucleon partonic structure.
2) Prompt photons in the final state of high energy collisions (Fig. 1b and c) allow for a detailed study of pQCD and of the hadronic structure of the incoming particles. The term "prompt" refers to photons which are radiated directly from the partons of the hard interaction. In contrast

to jets, photons are not affected by hadronisation, resulting in a more direct correspondence to the underlying partonic event structure.

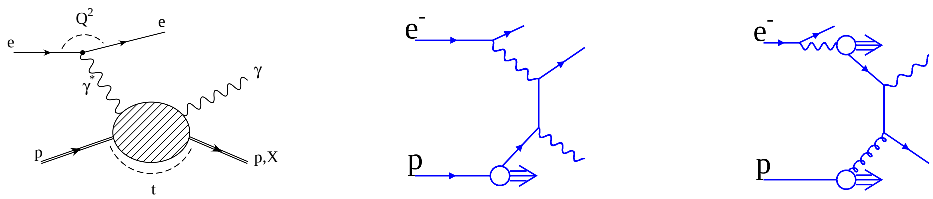

Figure 1: a) DVCS b) Direct Prompt γp c) Resolved Prompt γp

2 Deeply Virtual Compton Scattering

DVCS cross section measurements [1,2] at HERA, similar to diffractive vector meson electroproduction [3] but with a real photon replacing the final state vector meson, become an important source of information to study the partons, in particular gluons, inside the proton for nonforward kinematics and its relation with the forward one. In hard exclusive production the proton structure has to be encoded in a generalized form (Generalised Parton Distributions or GPDs) to include the difference of longitudinal momentum fractions of the two partons, ξ and transverse momentum exchange at the proton vertex.

This paper presents a measurement of DVCS cross section based on $46.5pb^{-1}$ of data collected with the H1 detector at HERA in years 1996 to 2000 [4]. The cross section is presented as a function of Q^2, W and t.

2.1 Data Analysis

At the present small values of $|t|$ the reaction $ep \to e\gamma p$ is dominated by the purely electromagnetic Bethe-Heitler (BH) process whose cross section, depending only on QED calculations and proton elastic form factors, is precisely known and therefore can be subtracted. To enhance the ratio of selected DVCS events to BH events the outgoing photon is selected in the forward, or outgoing proton, region with transverse momentum larger than 1 GeV. Large values of the incoming photon virtuality Q^2 are selected by detecting the scattered electron in the backward calorimeter with energy larger than 15 GeV. The outgoing proton escapes down the beam-pipe in the forward direction. In order to reject inelastic and proton dissociation events, no further cluster in the calorimeters with energy above noise level is allowed and an absence of activity in forward detectors is required.

The selected DVCS sample contains 1243 events. To extract the cross section, the data are corrected for detector acceptance and initial state radiation using the Monte Carlo simulation program MILOU [5]. The measured $ep \to e\gamma p$ cross section is converted to the $\gamma^* p \to \gamma p$ cross section using equivalent photon approximation.

2.2 Results

For triggering reasons, the cross sections are measured separately in 1996-1997 and 1999-2000, covering different Q^2 ranges, and are then combined. The differential cross section in t is measured at two different Q^2 values as shown in Fig. 2. The t dependence is parametrised as $e^{-b|t|}$. Combining the two data sets, the t slope is measured to be $b = 6.02 \pm 0.35(\text{stat}) \pm 0.39(\text{sys})$ GeV^{-2} for $Q^2 = 8$ GeV^2 and $W = 82$ GeV.

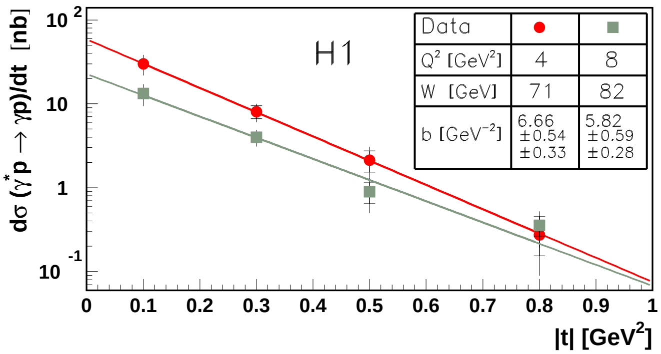

Figure 2: *The cross section $\gamma^* p \to \gamma p$ differential in t, for $Q^2 = 4$ GeV^2 and $Q^2 = 8$ GeV^2. The inner error bars represent the statistical and the full error bars the quadratic sum of the statistical and systematic uncertainties.*

Fig. 3 shows the cross section as a function of Q^2 for $W = 82$ GeV and as a function of W for $Q^2 = 8$ GeV^2. Fitting the Q^2 dependence with a form $(1/Q2)^n$ gives $n = 1.54 \pm 0.09(\text{stat}) \pm 0.04(\text{sys})$. Fitting the W dependence with a form W^δ gives $\delta = 0.77 \pm 0.23 \pm 0.19$. No Q^2 dependence is observed for δ. The steep rise of the cross section with W indicates the presence of a hard scattering process. The value of δ is similar to that measured in exclusive J/Ψ production. The new H1 measurement is found to be in agreement with the published ZEUS results [2]. Fig. 3 also compares the measurements with QCD predictions calculated at NLO by Freund and McDermott [6]. In this prediction, the classic PDF $q(x, \mu^2)$ of MRST2001 and CTEQ6 are used in the DGLAP region ($|x| > \xi$) such that $\mathcal{H}$, which is the only important GPD at small x is given at the scale μ by: $\mathcal{H}^q(x, \xi, t; \mu^2) = q(x; \mu^2)\, e^{-b|t|}$ for quark singlet and $\mathcal{H}^g(x, \xi, t; \mu^2) = x\ g(x; \mu^2)\, e^{-b|t|}$ for gluons, i.e. independent of the skewing parameter ξ, the skewing as the Q^2 dependences being generated dynamically (i.e. no intrinsic skewing). In the ERBL region ($|x| < \xi$), these parametrisations have to be modified, ensuring a smooth continuation to the DGLAP region [6]. The theoretical estimates agree well with the data for both shape and absolute normalisation. The uncertainty in the normalization for the theory is significantly reduced owing to the H1 measurement of the cross section (exponential) t slope; this uncertainty becomes smaller than the input PDF uncertainty which is quantified comparing MRST and CTEQ PDF set based predictions. Furthermore, this shows that no intrinsic skewing is needed to describe the DVCS cross section in the small Bjorken x region. Comparison to Colour dipole models also provide a reasonable description of the data (see [4]), both in shape and in normalisation. The Q^2 dependence is better described by the Favart-Machado prediction [7] when DGLAP evolution of the dipole is included.

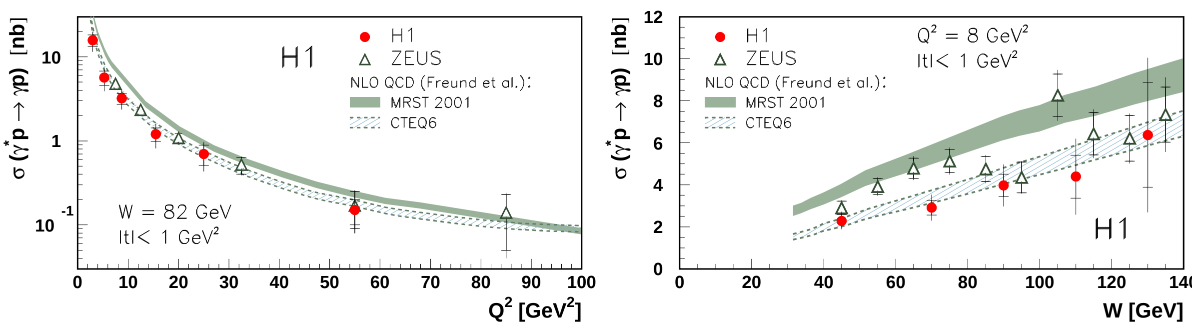

Figure 3: *The $\gamma^* p \to \gamma p$ cross section as a function of Q^2 for $W = 82$ GeV (left) and as a function of W for $Q^2 = 8$ GeV^2 (right). The H1 measurement is shown together with the results of ZEUS and NLO QCD predictions based on MRST 2001 and CTEQ6 PDFs. The band associated with each prediction corresponds to the uncertainty on the measured t-slope.*

3 Prompt Photon

Fig. 4a shows the differential inclusive prompt photon cross section $\mathrm{d}\sigma/\mathrm{d}\eta^\gamma$ as a function of the pseudorapidity of the photon in photoproduction regime ($Q^2 < 1\,\text{GeV}^2$ and $142 < W < 266\,\text{GeV}$) by H1 [8]. These results are compatible with ZEUS measurement [9] (not shown). A com-

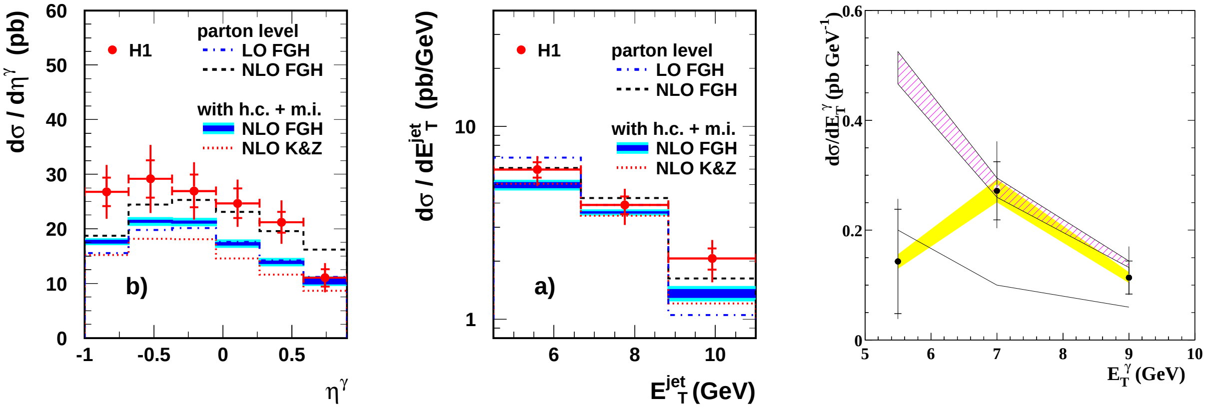

Figure 4: Prompt photon differential cross sections. **a)** in inclusive photoproduction, **b)** in photoproduction with jet, **c)** in DIS with jet - the hashed band represent the NLO QCD prediction, the full one the energy scale uncertainty.

parison to NLO pQCD calculations by Fontannaz, Guillet and Heinrich (FGH [10]) and Krawczyk and Zembrzuski (K&Z [11]) shows a good shape description but a normalisation $20\% - 40\%$ below the data. On Fig. 4b the cross section is shown differentially in the transverse jet energy, when an additional jet ($E_t > 4.5\,\mathrm{GeV}$ and $-1 < \eta^{jet} < 2.3$) is required. Here both NLO calculations [12,13] are consistent with the data in most bins. The hadronic and multiple interactions corrections improve the description of the data only in some regions. The ZEUS Collaboration [14] has measured the inclusive prompt photon in DIS ($Q^2 > 35\,\mathrm{GeV}^2$) with a jet ($E_T^{jet} > 6\,\mathrm{GeV}$ and $-1.5 < \eta^{jet} < 1.8$), see Fig. 4c. A pQCD calculation [15] to order $\mathcal{O}(\alpha^3\alpha_s^1)$ on parton level describes the normalisation except at low E_T and in the more forward (proton beam) direction. The PYTHIA and HERWIG Monte Carlo predictions undershoot the data in all cases (photoproduction and DIS), see [8,14] for more details.

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